BIOMETHANATION OF SEWAGE SLUDGE BY USING ULTRASONIC MEMBRANE ANAEROBIC SYSTEM (UMAS) USING SEWAGE SLUDGE AS SUBSTRATE

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ABSTRACT

This study is going to introduce Ultrasonic Membrane Anaerobic System (UMAS) as an alternative to current conventional methods to solve the problem of membrane fouling. Raw sewage sludge was treated by UMAS which consists of a cross flow ultra-filtration membrane (CUF) apparatus, while pH, pressure, and temperature parameter were kept constant during this experiment with the value of 7.0-7.6, 1.5 bars, and 32^{O}C respectively. Samples has been analyzed for several parameters such as chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), pH, volatile suspended solids (VSS), turbidity and colour, by controlling volatile fatty acids (VFA) and pH parameters. The initial value of COD recorded was 1040 mg/L; BOD was 98.7 mg/L, while TSS and VSS recorded the values of 98.6 mg/L, and 65.8 mg/L respectively. After 28 days of experiment, the final value of COD became 92 mg/L, BOD value dropped to 4.1 mg/L, TSS had final value of 6.0 mg/L while VSS dropped to 4.2 mg/L. The findings are this ultrasonicated-membrane technology has overcome fouling membrane, shorten the retention time of the sewage sludge treatment, reduce the treatment area, and high removal efficiency of Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS). The complete treatment reduced the COD content to 92 mg/L equivalent to a reduction of 91% reduction from the original, while TSS and VSS removal efficiency have reached up to 93%. The final product is Methane (CH_4) biogas, ranged from 79% to 96% which become a highly-demand in energy resource, at the same time this technology can reduce the greenhouse effect and global warming caused by the methane gas.

Key words: UMAS, wastewater, methane, membrane fouling, sludge

ABSTRAK

Kajian ini akan memperkenalkan Ultrasonik Membran Sistem Anaerobik (UMAS) sebagai alternatif kepada kaedah konvensional sedia ada bagi menyelesaikan masalah pengotoran membran. Enapcemar kumbahan mentah telah dirawat oleh UMAS yang terdiri daripada aliran merentas membran ultra-penapisan (CUF) radas, manakala pH, tekanan, dan parameter suhu telah dimalarkan dalam eksperimen ini dengan nilai 7,0-7,6, 1.5 bar, dan masing-masing 32^{O}C. Sampel telah dianalisis untuk beberapa parameter seperti permintaan oksigen kimia (COD), permintaan oksigen biokimia (BOD), jumlah pepejal terampai (TSS), pH, pepejal terampai meruap (VSS), dengan mengawal asid lemak meruap (VFA) dan parameter pH. Nilai awal COD yang dicatatkan adalah 1040 mg / L; BOD adalah 98.7 mg / L, manakala TSS dan VSS masing-masing mencatatkan nilai 98.6 mg / L, dan 65.8 mg / L. Setelah 28 hari eksperimen dijalankan, hasil terakhir ialah nilai COD menjadi 92 mg/L, BOD jatuh kepada 4.1 mg/L, TSS mempunyai hasil terakhir 6.0 mg/L sementara VSS jatuh kepada 4.2 mg/L. Hasil kajian adalah teknologi ultrasonic-membran ini telah mengatasi masalah pengotoran membran, memendekkan masa tahanan rawatan enapcemar kumbahan, mengurangkan kawasan rawatan, dan kecekapan penyingkiran yang tinggi keperluan oksigen kimia (COD), Pepejal Biokimia Oxygen Demand (BOD) dan Jumlah Terampai (TSS). Rawatan yang lengkap telah mengurangkan kandungan COD kepada 92 mg / L bersamaan dengan 91% pengurangan daripada nilai asal, manakala kecekapan penyingkiran TSS dan VSS telah mencapai sehingga 93%. Produk akhir adalah Metana (CH4) biogas, adalah di antara 79% hingga 96% yang menjadi permintaan tinggi dalam sumber tenaga, pada masa yang sama teknologi ini boleh mengurangkan kesan rumah hijau dan pemanasan global yang disebabkan oleh gas metana.

Kata Kunci: UMAS, air kumbahan, metana, pengotoran membran, kumbahan

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LIST OF ABBREVIATIONS/SYMBOLS

MAS	Membrane Anaerobic System
UMAS	Ultrasonic Membrane Anaerobic System
COD	Chemical Oxygen Demand
BOD	Biochemical Oxygen Demand
TSS	Total Suspended Solid
VSS	Volatile Suspended Solid
CH4	Methane Gas
H2O	Water
CO2	Carbon Dioxide
NH3	Ammonia
VFA	Volatile Fatty Acid
HCO3	Bicarbonate
HRT	Hyraulic Retention Time
PVC	Polyvinylchloride
CH3OH	Methanol
CH2O	Formaldehyde
CH3NO2	Nitromethane
CH3Cl	Chloroform
CCl4	Carbon Tetracholide
CUF	Cross Flow Ultrafiltration
NaOH	Sodium Hydroxide
MWCU	Molecular Weight Cut-Off
OLR	Organic Loading Rate
pKa	Dissociation Constant

CHAPTER 1

INTRODUCTION

1.1 Background

Sludge contains large amounts of pathogenic organisms and heavy metals, which are harmful to human health and the environment (US EPA, 2007). Therefore, useful and effective methods are needed to remove pollutants, such as organic micro-pollutants and heavy metals (Xu et al.,2013). Anaerobic digestion can regenerate electricity and heat by using the methane produced by sewage sludge. Sewage sludge (SS) from wastewater treatment plant, which is accompanied with unpleasant odors, pathogens, and heavy metals (HMs), has been deemed as a common pollution source (Huang et al.,2011;Li et al.,2012).Besides, accompanied with the high water content and large production, conventional treatment processes (e.g. agricultural application, landfilling) of SS are becoming increasing complex. Furthermore, the rigorous requirement of environmental protection has limited the application of conventional treatment processes and gives rise to the treatment of SS an urgent issue to tackle. On the other hand, due to the high contents of organic matter, nitrogen and phosphorus, SS has been viewed as a promising alternative source of energy (Zhai et al., 2014).The anaerobic degradation of complex organic matter to methane (CH_4) and carbon dioxide (CO_2), which involves the interaction of four different metabolic groups of bacteria, namely hydrolytic, acidogenic, acetogenic and methanogenic bacteria, (Kataoka et al.,1992) offers, in general, some significant advantages when compared to aerobic treatment. These are: less production of sludge, low nutritional requirements, ability to deal with high organic loads, low cost and finally biogas (CH_4) production (Kappell et al.,2005) .In this case, Anaerobic digestion is one of the most important processes used for various industrial wastewaters as well as sewage treatments because it combines pollution reduction and energy production. (Lin et al., 2013). An improvement in the efficiency of anaerobic digestion can be brought about by either suitably modifying the existing digester design or by incorporating appropriate advanced techniques. Thus, UMAS is found to be superior to the conventional processes due to low concentrations of VFA in the effluent, a high degree of sludge retention and stable reactor performance. UMAS which the membrane is ultrasonicated, it is designed to create high energy compared to normal Membrane Anaerobic System (MAS) to clean the waste of filter. Besides, the ultrafiltration membrane which has high permeability and porosity properties, is important for the membrane to filter waste easily. In recent times biomethanation technology has become more attractive source of renewable energy due to reduced technological cost and process efficiency. Different variety of substrates are extensively used in this anaerobic technology. Methane production through biomethanation technology has been evaluated as one of the most energy-efficient and environmentally benign way of producing vehicle biofuels and can provide multiple benefits to the users. In biomethanation process the organic waste is converted into energy (methane) (Weiland, 2012). It is also now a well-accepted fact that methane is a powerful greenhouse gas, each molecule of methane causes about 25 times more global warming than a molecule of CO_2 (IPCC,2007). If we do not process organic waste and recover methane from it but, instead, allow the waste to rot in the open we will let the methane escape into atmosphere to cause global warming (Abbasi et al.,2010). However, this issue could be resolved by applying membrane separation in anaerobic processes as the membrane can retain biomass (methane) effectively, producing a solids-free effluent and prevent unintended sludge wasting. Short HRT coupled with long solids retention time (SRT) to achieve high biomass concentration in a bioreactor is now possible through the use of membrane for solids-liquid separation (Huang et al.,2010).

1.2 Problem Statement

The sewage sludge wastewater will be treated using Membrane Anaerobic System (MAS) under anaerobic digestion method. Still, the main problem that always occurs in this system is membrane fouling. Membrane fouling is a process where solute or particles deposit onto a membrane surface or into membrane pores in a way that degrades the membrane's performance. The quality of the water produced will be affected and severe flux declined will occur when membrane fouling happens. To overcome this problem, membrane replacement or chemical cleaning will take place, but these will increase the operating costs of a treatment plant. Therefore, another economic solution to overcome this problem is by adding ultrasonicated-device into the MAS system. This is a new design that was proposed by NH Abdurahman *et.al*, (2012) in treating POME and producing methane. Still there are few things that have to be upgraded to improve the Ultrasonic Membrane Anaerobic System (UMAS) to produce methane gas. Furthermore, other problems that related to the conventional methods are:

i) The conventional techniques take times to accomplish and are costly.
ii) Expensive and high cost for raw materials treatment.
iii) High demand of energy.
iv) Limited resources.
v) Lack to retain the biogas

1.3 Objectives

The following are the objectives of this research:

i) To experimentally evaluate the removal of COD, BOD, TSS, and VSS.
ii) To evaluate the performance of UMAS in treating raw sewage sludge.
iii) To evaluate the effect of organic loading rate (OLR) in UMAS performance.

1.4 Scope of Study

The following are the scope of this research:

i) Design a 100 L UMAS to treat sewage sludge wastewater.
ii) To analyze the parameters such as BOD, COD, TSS, VSS, pH and colour.
iii) To measure the percentage of methane gas production by using J-Tube Gas Analyzer.
iv) To determine the amount of methane gas produced by the volume of permeates

1.5 Rational and Significance

The following are the contributions of this study:

i) Energy saving.
ii) Less expensive treatment.
iii) Environmental friendly (comply with standard issue).
iv) Can reduce the organic matter in the sewage sludge.
v) Reduce retention time.
vi) Overcome membrane fouling problem.
vii) Production of methane gas (CH_4) from waste.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There are mainly two ways to treat raw sewage sludge. First with aerobic process and second is anaerobic process. Aerobic process is the process in which the microorganisms breakdown all the biodegradable materials with presence of oxygen. This process is quite expensive treatment because it uses oxygen in the process of treating sewage sludge. Since the percentage of raw sewage sludge disposal is increasing daily so this technique is not convenient anymore. People started to find other alternative ways to treat their raw sewage sludge and found that, anaerobic process is the best way to treat their raw sewage sludge.

2.2 Raw Sewage Sludge

Raw sewage sludge is a muddy like, yellowish colour and has a bad smell. It is slurry with water content and rich in nutrient such as organic matter derived from human, animal and food wastes. Other constituents are trace contamination mainly from industrial effluents and bacteria. (B.R.Gurjar,2001). Basically, there are 2 methods to treat the sewage sludge which are aerobic process and anaerobic process then only it can be dispose. Before dispose to landfill site, it will undergo thickening and dewatering process to increase the solid concentration of sludge and decrease its volume by removing a portion of the water. (IzrailS.Turovskiy et al, 2006).

2.3 Aerobic Digestion

Aerobic digestion is the conventional technique to treat a wide range of sludge. It is a process of oxidation and decomposition of the organic part of the sludge by microorganism in special open or enclosed tank with the presence of oxygen (Izrail S.Turovskiy et al, 2006).The process produce stable product. The stable product means the sludge is reduce in mass, volume, pathogenic organisms and does not have bad smell. This process has advantages and disadvantages. The major advantages of this process are odourless and easier to operate. The major disadvantage is the operating cost higher since it used oxygen in this process. So, people start to find alternative method in order to reduce the cost for sludge treatment.

2.3.1 Process Theory

Aerobic digestion is a continuous process. When the soluble substrate is completely been consumed by the bacteria, the bacteria begin to consume their protoplasm to obtain the energy for cell maintenance. This phenomenon is called *endogenous respiration*. This is the major reaction in aerobic process. The cell is oxidized aerobically to produce carbon dioxide (CO_2), water (H_2O) and ammonia (NH_3) (IzrailS.Turovskiy et al,2006).

2.3.2 Conventional Aerobic Digestion

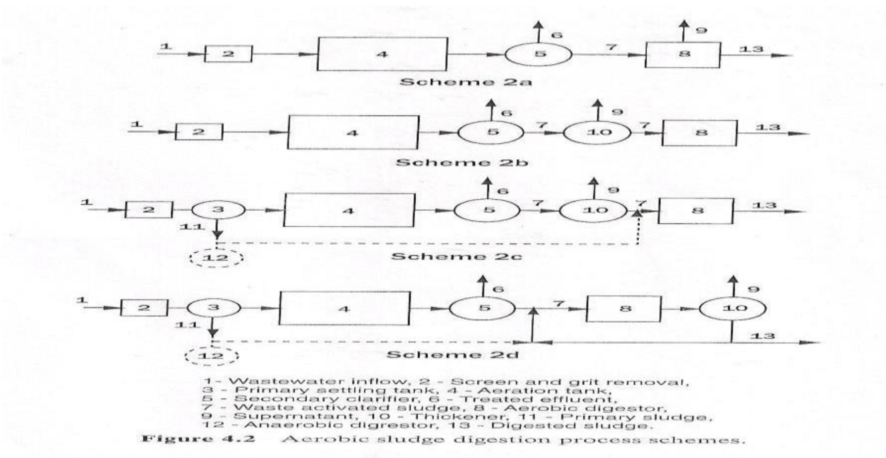

Figure 2-1: Aerobic Sludge Digestion Process Scheme Taken from (IzrailS.Turovskiy et al, 2006)

For wastewater treatment plant without primary settling tank, scheme 2a and 2b is recommended. In scheme 2a, the activated sludge goes to the aerobic digester directly from secondary clarifier. The sludge goes to the digester after preliminary concentration in a sludge thickener. Scheme 2c and 2d are the common process used to treat raw sewage sludge from small to medium size wastewater treatment plant. In 2c, thickened secondary sludge is combined with primary sludge and discharged to the digester. For 2d, combined primary and unthickened secondary sludge is digested first and thickened in a thickener (IzrailS.Turovskiy et al,2006).

2.4 Anaerobic Digestion

Anaerobic digester has been used as an alternative way to treat raw sewage sludge. It is the process by which organic materials in this case is raw sewage sludge is fermented or has been breakdown by bacteria in the absence of oxygen (LudovicoSpinosa,2007). This process basically do the same this as aerobic process did, like produce stable sewage sludge, but the different between this 2 methods is the by-products. In anaerobic process, it will produce methane gas (CH_4) as its by-product but in aerobic process not. So, anaerobic process is a preferable method to treat raw sewage sludge in the industry. The stable sewage sludge can be used as a soil conditioner or fertilizer (LudovicoSpinosa, 2007). There have two types of anaerobic digestion which are mesophilic and thermophilic digestion.

2.4.1 Mesophilic Digestion

Mesophilic digestion operates at ambient temperature at 35-45$_0$C. The optimum temperature of the mesophilic methane bacteria is 37$_0$C. For simplicity of the operation and to avoid the need to heat the reactor, most anaerobic digestion plants are operated at mesophilic temperatures that at temperatures between 3°C and 35°C and require 15 to 20 days of mean retention time in the digestion reactor, but it is not so efficient in reducing the total suspended solid and deactivation of pathogenic microorganisms (Young-Chae Song et al,2004).

2.4.2 Thermophilic Digestion

Thermophilic digestion using higher metabolic rate of thermophilic microorganisms has become a favourable technique recently. (Aoki N and Kawase M, 1991). Theoretically, the reaction rate of thermophilic digestion is double than mesophilic rate. The operation temperature of thermophilic process is between 55^{0}C to 60^{0}C. Although better performance of reduction of volatile solid and deactivation of pathogen organism can be obtained from thermophilic digestion, the effluent quality and ability of dewatering the residue is poor and required heat energy to heat the digester (FangHHP and ChungDWC, 1999; Maibaum C and Kuehn V.,1999; Kim M,2002). Moreover, the thermophilic digestion suffer from high amount of free ammonia, which plays an inhibiting role for the microorganisms; but the increasing pKa of the volatile fatty acid (VFA) will make the process more susceptible to inhibition (Boe K.,2006), thus make the thermophilic is very sensitive process than mesophilic process.

2.4.3 Process Theory

Anaerobic digestion involves bacterial fermentation of organic substances in the absence of free oxygen (Abbasi T et al., 2012a). The fermentation leads to the breakdown of complex biodegradable organics in a four step process (Khanal, 2008; Rosenzweig and Ragsdale, 2011) (Fig. 2-2). It is also referred as a three-phase process: hydrolytic phase (step 1), acid phase (steps 2 and 3), and methane phase (step 4). The steps are:

1.Decomposition of fats, cellulose, starch, proteins and other macromolecules into simpler,water soluble, monomers: amino acids, long-chain fatty acids, and sugars. This is brought about by exoenzymes (hydrolase) present in facultative and obligatory anaerobic bacteria.

2. Conversion of monomers during acidogenesis to form shorterchain (C1-C5) ‘volatile fatty acids’ (VFAs), principally lactic, propionic, butyric, and valeric acid.

3. Consumption of VFAs by homoacetogenic microorganisms to generate acetic acid, carbon dioxide, and hydrogen.

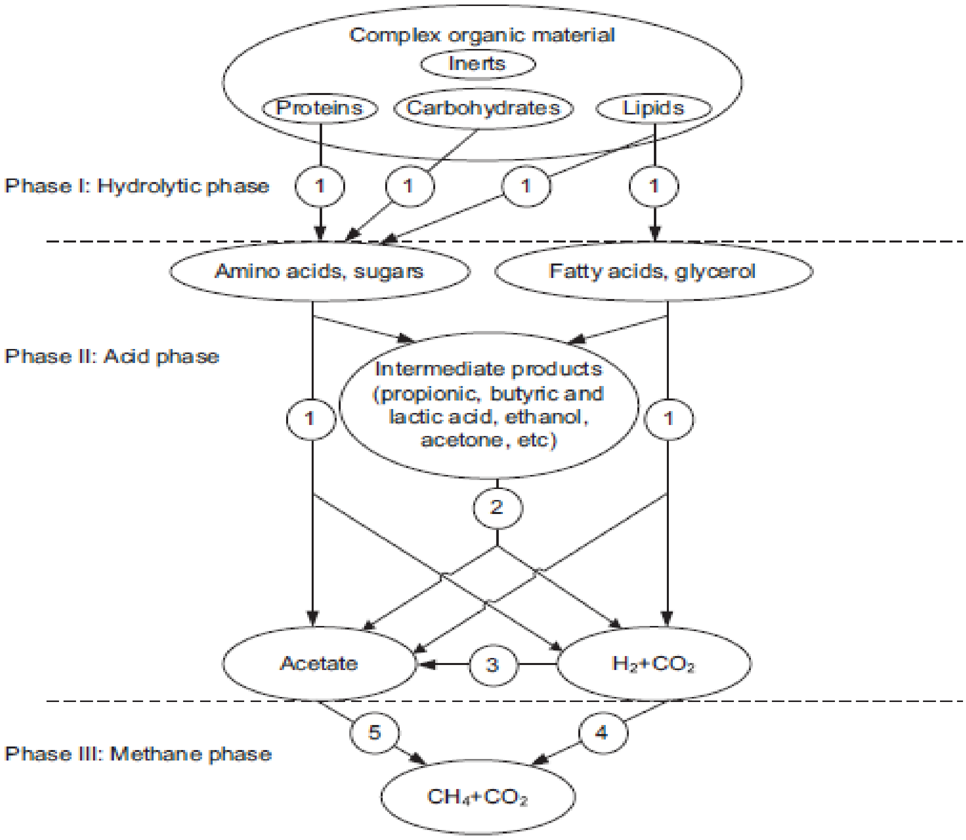

Figure 2-2: Steps associated with anaerobic digestion of organic materials

The bacteria involved are: (1) Hydrolytic and fermentative; (2) hydrogen producing acetogenic (3) hydrogen consuming acetogenic (4) carbon dioxide reducing and (5) aceticlastic methanogenic.

4. Methanogenesis: action of the strictly anaerobic methanogenic bacteria on the acetate, hydrogen, and some of the carbon dioxide to produce methane. Three biochemical pathways are used by methanogens to achieve this (Galagan et al., 2002);

a) acetotrophic pathway ($4CH_3COOH \rightarrow 4CO_2 + 4CH_4$);

b) hydrogenotrophic pathway ($CO2 + 4H_2 \rightarrow CH4 + 2H_2O$); and

c) methylotrophic pathway ($4CH_3OH + 6H_2 \rightarrow 3CH_4 + 2H_2O$).

Of these, the acetotrophic pathway is the primary one; hence theoretical yield calculations are often made using this pathway (Zhang et al., 2010). Methylated substrates other than methanol can also be converted. The gaseous products of step IV include 40-70% methane, CO2, and traces of other gases. This mixture is commonly referred as biogas (S.M. Tauseef et al.,2013)

2.5 Anaerobic Microorganism

2.5.1 Acidogenic Bacteria

The essential organics in wastewater are proteins, lipids and hydrocarbon. All of it can be breakdown into simple monomer by acidogenic bacteria. Proteins are hydrolyzed into amino acid by protease enzyme. Lipids are converted from glycerin by lipase enzyme and the polymeric hydrocarbon are converted into glucose and other sugar via exo-enzyme (UdoWiesman et al,2007) .

2.5.2 Acetogenic Bacteria

Most of acetate is formed by synthrophic reaction, and only little of acetate is formed through direct fermentation (UdoWiesman et al, 2007). This bacterium is able to converted carbon dioxide into acetate via the acetylcoenzyme A (acetyl-CoA).

2.5.3 Methanogenic Bacteria

There are 2 types of bacteria which are Methanosacina and methanothrix. It can grow using acetate. 70% of methane gas (CH_4) is formed in digester process. Methanosacina can produce ATP from acetate and water. Methanol and methyl amine are intermediate product that can be degraded down to methane gas (CH_4) and carbon dioxide (CO_2) (UdoWiesman et al, 2007).

2.6 Factors Which Influence Anaerobic Digestion Of An Organic Substrate

Presence of adequate quantities of nitrogen, micronutrients, and water is essential if an organic substrate is to undergo anaerobic digestion and generate methane-rich biogas (Singh et al.,1999,Takashima et al.,2011). These are essentially the requirements of microorganisms especially methanogenic bacteria. Because these microorganisms are the ‘workers’ who take the fermentation along the desired route and at optimum pace, generating conditions which help these microorganisms ensures success of the process (Abbasi et al.,2012,Demirel B. and Scherer P.,2008). Some of the aspects which have to be kept in view for successful operation of an anaerobic digestion process for obtaining biogas are recounted below.

2.6.1 Dilution

Water should be added, if necessary, to the raw material to generate a slurry which is neither too thick nor too thin. If a material is diluted too much, the solid particles may settle down in the digester and may not get degraded properly. If the slurry is too thick, it may be difficult to stir and may impede the flow of gas to the upper part of the digester (Abbasi et al.,1992,Nipaney et al.,1992). Different systems can handle different levels of slurry density, generally in the range of 10–25% of solids (Abbasi et al.,2012).

2.6.2 pH Control

pH is an important factor for keeping functional anaerobic digestion. A typical pH is in the range of 6.5-7.6 (Parkin and Owen 1986). The accumulation of intermediate acids leads to pH drop during fermentation. In order to maintain stable operation, it is necessary to add bicarbonate or carbonate as an alkalinity buffer to neutralize volatile fatty acids and carbon dioxide (Parkin and
Owen 1986).

2.6.3 Temperature

The effects of temperature on anaerobic digestion are well recognized. Mesophilic (25-45^{0}C) and thermophilic (45-65^{0}C) anaerobic digestion are commonly applied in the field (O'Reilly et al. 2009). Most full-scale anaerobic digesters are operated at mesophilic temperature (Parkin and Owen 1986). Previous studies revealed several advantages of thermophilic digestion, including high organic removal rate, high degree of degradation and excellent solids stabilization (Buhr and Andrews 1977). Since wastewater and biosolids is discharged at relatively low temperature (e.g., 18 ^{0}C), recent research toward anaerobic treatment under psychrophilical condition becomes attractive. For instance, microbial communities involved in digestion are sensitive to temperature changes. However, researchers discovered that anaerobic digestion at low temperature showed reproducible microbial community structure and operational performance, suggesting that optimal cultivation of hydrogenotrophic methanogens is a effective way to improve process efficiency (O'Reilly et al. 2009). The rate of anaerobic degradation of organic substrates generally increases in the order of psychrophilic, mesophilic and thermophilic digestion. However, anaerobic digestion was traditionally operated in mesophilic range (25–45^{0}C) because of heat generation through methane combustion (Donoso-Bravo et al. 2009).

2.6.4 Retention Time

Most anaerobic systems are designed to retain the waste for a fixed number of days. Number of days the materials stays in the tank is called the Hydraulic Retention Time or HRT (Dennis A and Burke PE, 2001). The Hydraulic Retention Time is equal to the volume of the tank divided by the daily flow, HRT = Volume (V)/Flow (Q). In tropical countries like India, HRT varies from 30 to 50 days and is dependent on the weather conditions (Singh H and Maheshwari RC.,1995). HRT is important since it establishes the quantity of time available for bacterial growth and subsequent conversion of the organic material to gas. The HRT vary with the feedstocks, concentration of solids and temperature. Increase in temperature reduces the HRT of substrate into the digesters.

2.6.5 Light

Light does not kill methanogens but strongly inhibits methanation. Hence light should be blocked from entering the anaerobic digestion chamber.

2.7 Previous work on Anaerobic Treatment Methods

2.7.1 Fluidized bed reactor

Fluidize bed reactor can be used to carry out a variety of multiphase chemical reactions, and it exhibits several advantages that make it useful for treatment of high-strength wastewaters (NH Abdurahman et.al, 2012). Hickey and Switzenbaum (1988) reported on the development of the anaerobic expanded bed process, which was found to convert dilute organic wastes to methane at low temperatures and at high organic and hydraulic loading rates. Sen S and Demirer GN had done research on anaerobic treatment of real textile wastewater with a fluidized bed reactor. During the operation period, real cotton textile wastewater was fed to the anaerobic FBR. To achieve the maximum colour removal efficiency in the reactor, the effect of operational conditions was investigated. Based on the results obtained, it shows that anaerobic treatment for textile wastewater was possible as the amount of corresponding maximum COD, BOD, and colour removals were found to be around 82%, 94% and 59%, respectively. But, by increasing the external carbon source to be added into the real textile wastewater, the colour removal efficiency of the anaerobic FBR reactor will not increase. John S. Jeris reported that wastes containing from 5,000 to 54,000 mg/ℓ, were treated with 65 to 95 percent COD removal in 0.3 to 4.9 days hydraulic detention time. An energy comparison showed anaerobic treatment to produce a positive energy balance compared to an energy need for comparable activated sludge treatment. By using fluidized bed reactor, there are different COD removal efficiencies with every different types of waste. Based on POME waste water treatment, (Borja et al., 1995) reported that the COD removal efficiency is 78% to 94%. Hawkers et al., (1995) found that fluidized bed using granular activated carbon (GAC) gave about 60% COD removal. This shows that only suitable support material can be used using fluidized bed reactor to obtain high COD removal efficiency in the system.

2.7.2 Up-flow Anaerobic Sludge Blanket (UASB) Reactor

SE Nayono had been conducted on anaerobic treatment of waste water sugar cane recently by using Up-flow Anaerobic Sludge Blanket (UASB) reactor. The reactor was water jacketed and operated at constant temperature of 37^{o}C. Figure 2-3 shows the schematic diagram of UASB reactor.

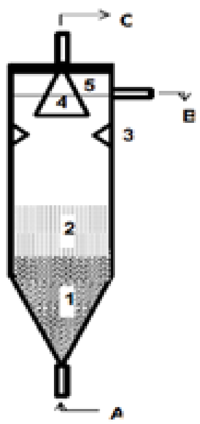

Figure 2-3: Typical cross section of a UASB reactor

On the 18th week of operation, the reactor experienced a failure at the thermostat due to twisting of warm jacket tube. This failure causes a temperature drop from 32^oC to about 24^oC. This effects the COD efficiency removal. The COD removal efficiency was also hindered when the temperature was suddenly dropped. It took 5 weeks to reach 80% of COD removal efficiency. This temperature decrease occurred when the operation of the reactor was considered as not yet stable after increment of its organic loading rate (COD removal efficiency has not yet reached 80 % and residual fatty acids concentration in the effluent were more than 10mM). The combination of both conditions caused the COD removal efficiency of the reactor dropped from 73 % to 59 % (SE Nayono, 2012).

Hampannavar and Shivayogimath conducted the experiment of anaerobic treatment on waste water of sugarcane industry, using UASB reactor. It is reported that the maximum COD removal efficiency of 89.4% was achieved. The COD rate linearly increases with the increase of OLR. The ratio of VFA to alkalinity is varied between 0.190.33 during the treatment. The methane content in the biogas was found to be between 73 and 82% at steady state conditions. This shows that anaerobic treatment is feasible in treating waste water of sugar industry.

Carol Connin (1996) had conduct a research on anaerobic treatment of brewery waste water using a UASB reactor seeded with activated sludge. Two UASB reactors were set up at the temperature range between 19^0C to 23^0C. The average sludge loading rate was different for both reactors since each was seeded with a different amount of sludge. Reactor B was seeded with 5.93 g VSS/l, while Reactor A was seeded with 1.98 g VSS/l, so that the sludge loading rate of Reactor A was about three times more than Reactor B. The methane composition content from both reactors increased as the HRT was reduced. Hickey et al., (1991) reported that brewery wastewater treated at an operating temperature of 19 – 23 ^0C inoculated with digested sewage sludge and activated sludge took 12 months to achieve the 90% of efficiency COD removal. The lower methanogenic activity of this sludge caused the methane biogas content on both reactors low (C Carol, 1996).

T.A. Elmitwalli, M. Shalabi, C. Wendland and R. Otterpohl have made a research on grey water treatment in UASB reactor at ambient temperature. The batchrecirculation experiments showed that a maximum total-COD removal of 79% can be obtained in grey-watertreatment in the UASB reactor. In the first phase, at the lowest temperature of 18^0C, the reactor has the lowest COD removal. For the second phase, the UASB reactor had the highest total-COD removal of41%, because the reactor was operated in the summer period at an average wastewatertemperature of 23^0C. When the HRT decreased to 8 hours at 20^0C at the third phase, the total COD removal decreased to 31%. Based on the result obtained, the removal of colloidal COD depended on the wastewater temperature, while the removal ofsuspended and dissolved COD depended on the wastewater temperature and the HRT of the UASB reactor.

The conventional UASB reactor concept showed severe limitations, mainly owing to problems related to mass transfer resistance and/or the existence of concentration gradients inside the systems. If the biogas production rate drops, e.g. for low-strength or cold wastewater, the degree of mixing must be raised hydraulically to ensure the required mass transfer (Van Lier et al, 2001).

2.7.3 Anaerobic Filtration

The anaerobic filter process was first developed by Coulter (1957) but was virtually forgotten until 1969 when Young and McCarty (1969) renewed interest by demonstrating the process's ability to treat a medium to high strength carbohydrate/protein wastewater (PY Chung, 1982).

PY Alice Chung (1982) conducted an experiment using anaerobic filtration. The anaerobic filtration was seeded by 30 gallons of sludge from apilot scale 50-gallon digester. During the entire experiment, the aerobic filter was effective in treating the oxygen demanding forms of nitrogen and sulphides produced during anaerobic fermentation. A total of 5971.9 gm of COD was removed, resulting in an apparent yield of 0.0019 gm VSS/gm COD removed. The values reported by Chain (1976) and Young and McCarty (1968) were 0.012 gm and 0.015 gm VSS/gm COD for fatty acid waste respectively (PYC Chung, 1982). The value in this experiment calculated is relatively low due to the sludge could only be partially drained. If the accumulation of the biological solids onto the plastic media were also measured, a higher yield would also be obtained. From this experiment, it concludes that the low production of biogas methane is due to two factors; low organic loading rates, and a few amounts of methane are loss through the effluent even though methane gas are considered as insoluble.

Anaerobic filters are capable of treating wastewaters to obtain good effluent quality with at least 70% of COD removal efficiency with methane gas composition of more than 50% (NH Abdurahman et al., 2012). But, clogging of anaerobic filter is a major disadvantage that always occur in the process (Bodkhe, 2008), (Jawed et al., 2000), (Parawira et al., 2006). Clogging usually occurs during the treatment process of POME (Borja et al., 1995b), and slaughterhouse wastewater. This is due to the high organic loading rate (OLR) which had higher suspended solid content compared to the lower one.

2.7.4 Anaerobic Contact Digester

All anaerobic digesters perform the same basic function. They hold manure in the absence of oxygen and maintain the proper conditions for methane forming microorganisms to grow. (WH Douglas, 2009). Anaerobic digesters are the aerobic equivalents of activated sludge process and are currently used for treating effluents from sugar processing, distilleries, citric acid and yeast production, industries producing canned vegetables, pectin, starch, meat products, etc. (NH Abdurahman et al., 2012).

Dennis A. Burke P.E (2001) conducted an experiment on dairy waste anaerobic treatment. Recent tests have established that screen and gravity separators can remove 75% to 80 % of the COD present in the waste stream. In one test the dairy parlor COD was reduced from 31,000 mg/l to 8,600 mg/l in the effluent from the gravity separator. In another the flush water influent to a separator system was 10,900mg/L while the effluent was 1,800 mg/L.

2.7.5 Membrane Separation Anaerobic (Mas) Treatment Process

This technology is still in a development stage. One of the studies for the treatment process by using membrane anaerobic processes is food industry (M Claudia et al., 2012).MF and UF systems can reduce suspended solids and microorganisms, whilst UF/RO combinations can also remove dissolved solids and provide a supply of process water and simultaneously reducing waste streams. UF systems can get more than 90% reduction in BOD and less than